

WHAT IS CLAIMED IS:

- 1 1. A magnetoresistive head comprising:
2 a pinned layer;
3 a free layer; and
4 a non-magnetic spacer film formed between the pinned layer and the free layer;
5 wherein the pinned layer has a first ferromagnetic film and a second
6 ferromagnetic film anti-ferromagnetically coupled to each other by way of an anti-ferromagnetic
7 coupling film; and
8 a coercivity of the first ferromagnetic film is 200 Oe or more and a coercivity of
9 the second ferromagnetic film is 20 Oe or less.

- 1 2. A magnetoresistive head comprising:
2 a pinned layer;
3 a free layer; and
4 a non-magnetic spacer film formed between the pinned layer and the free layer;
5 wherein the pinned layer has a first ferromagnetic film and a second
6 ferromagnetic film anti-ferromagnetically coupled to each other by way of an anti-ferromagnetic
7 coupling film;
8 a composition of the first ferromagnetic film is within a range of: $\text{Co}_{100-x}\text{Fe}_x$
9 (at%) $40 \leq X \leq 80$; and
10 a composition of the second ferromagnetic film is within a range of: $\text{Co}_{100-y}\text{Fe}_y$
11 (at%) $0 \leq Y \leq 20$.

- 1 3. A magnetoresistive head according to claim 1 or 2, wherein the anti-
2 ferromagnetic coupling film is formed of Ru and has a thickness within a range from 3.0 to
3 4.0 Å.

- 1 4. A magnetoresistive head according to claim 1 or 2, wherein a relation between
2 an imaginal thickness DA0 of the first ferromagnetic film that has a magnetic moment equal to a
3 magnetic moment of the second ferromagnetic film and a thickness DA of the first ferromagnetic
4 film satisfies:

5 $0.0227 \leq (DA - DA0)/DA0 \leq 0.136$.

1 5. A magnetoresistive head according to claim 4, wherein the magnetic moment
2 of the first ferromagnetic film is larger than that of the second ferromagnetic film.

1 6. A magnetoresistive head according to claim 1 or 2, wherein a layer in contact
2 with the first ferromagnetic film is formed from one of Ru, Ta, Cu, and NiFeCr.

1 7. A magnetoresistive head according to claim 1 or 2, wherein:
2 the free layer is on the side of a substrate and the pinned layer is on a side remote
3 from the substrate relative to the free layer; and
4 wherein the magnetoresistive head has an underlayer adjacent to the free layer,
5 the underlayer having an NiFeCr layer on the side of the substrate.

1 8. A magnetoresistive head according to claim 3, wherein:
2 the free layer is on the side of a substrate and the pinned layer is on a side remote
3 from the substrate relative to the free layer; and
4 wherein the magnetoresistive head has an underlayer adjacent to the free layer,
5 the underlayer having an NiFeCr layer on the side of the substrate.

1 9. A magnetoresistive head according to claim 4, wherein:
2 the free layer is on the side of a substrate and the pinned layer is on a side remote
3 from the substrate relative to the free layer; and
4 wherein the magnetoresistive head has an underlayer adjacent to the free layer,
5 the underlayer having an NiFeCr layer on the side of the substrate.

1 10. A magnetoresistive head according to claim 5, wherein:
2 the free layer is on the side of a substrate and the pinned layer is on a side remote
3 from the substrate relative to the free layer; and
4 wherein the magnetoresistive head has an underlayer adjacent to the free layer,
5 the underlayer having an NiFeCr layer on the side of the substrate.

1 11. A magnetoresistive head according to claim 6, wherein:

2 the free layer is on the side of a substrate and the pinned layer is on a side remote
3 from the substrate relative to the free layer; and

4 wherein the magnetoresistive head has an underlayer adjacent to the free layer,
5 the underlayer having an NiFeCr layer on the side of the substrate.

1 12. A magnetoresistive head according to claim 1 or 2, wherein:

2 the pinned layer is on the side of the substrate and the free layer is on a side
3 remote from the substrate relative to the pinned layer; and

4 wherein an underlayer adjacent to the first ferromagnetic film on the side of the
5 substrate comprises a stack of NiFeCr and Ru, a stack of NiFeCr, Ru, and NiFe, or a stack of
6 NiFeCr, Ru, NiFe and Cu, in order from the side of the substrate.

1 13. A magnetoresistive head according to claim 3, wherein:

2 the pinned layer is on the side of the substrate and the free layer is on a side
3 remote from the substrate relative to the pinned layer; and

4 wherein an underlayer adjacent to the first ferromagnetic film on the side of the
5 substrate comprises a stack of NiFeCr and Ru, a stack of NiFeCr, Ru, and NiFe, or a stack of
6 NiFeCr, Ru, NiFe and Cu, in order from the side of the substrate.

1 14. A magnetoresistive head according to claim 4, wherein:

2 the pinned layer is on the side of the substrate and the free layer is on a side
3 remote from the substrate relative to the pinned layer; and

4 wherein an underlayer adjacent to the first ferromagnetic film on the side of the
5 substrate comprises a stack of NiFeCr and Ru, a stack of NiFeCr, Ru, and NiFe, or a stack of
6 NiFeCr, Ru, NiFe and Cu, in order from the side of the substrate.

1 15. A magnetoresistive head according to claim 5, wherein:

2 the pinned layer is on the side of the substrate and the free layer is on a side
3 remote from the substrate relative to the pinned layer; and

4 wherein an underlayer adjacent to the first ferromagnetic film on the side of the
5 substrate comprises a stack of NiFeCr and Ru, a stack of NiFeCr, Ru, and NiFe, or a stack of
6 NiFeCr, Ru, NiFe and Cu, in order from the side of the substrate.

1 16. A magnetoresistive head according to claim 6, wherein:

2 the pinned layer is on the side of the substrate and the free layer is on a side

3 remote from the substrate relative to the pinned layer; and

4 wherein an underlayer adjacent to the first ferromagnetic film on the side of the

5 substrate comprises a stack of NiFeCr and Ru, a stack of NiFeCr, Ru, and NiFe, or a stack of

6 NiFeCr, Ru, NiFe and Cu, in order from the side of the substrate.

1 17. A magnetoresistive head according to claim 1 or 2, wherein:

2 the fixed layer is on the side of a substrate and the free layer is on a side remote

3 from the substrate relative to the fixed layer; and

4 an underlayer adjacent to the first ferromagnetic film on the side of the substrate

5 comprises a stack of NiFeCr, NiFe, PtMn and Ru, or a stack of NiFeCr, NiFe, PtMn and Cu, in

6 order from the side of the substrate.

1 18. A magnetoresistive head according to claim 3, wherein:

2 the fixed layer is on the side of a substrate and the free layer is on a side remote

3 from the substrate relative to the fixed layer; and

4 an underlayer adjacent to the first ferromagnetic film on the side of the substrate

5 comprises a stack of NiFeCr, NiFe, PtMn and Ru, or a stack of NiFeCr, NiFe, PtMn and Cu, in

6 order from the side of the substrate.

1 19. A magnetoresistive head according to claim 4, wherein:

2 the fixed layer is on the side of a substrate and the free layer is on a side remote

3 from the substrate relative to the fixed layer; and

4 an underlayer adjacent to the first ferromagnetic film on the side of the substrate

5 comprises a stack of NiFeCr, NiFe, PtMn and Ru, or a stack of NiFeCr, NiFe, PtMn and Cu, in

6 order from the side of the substrate.

1 20. A magnetoresistive head according to claim 5, wherein:

2 the fixed layer is on the side of a substrate and the free layer is on a side remote

3 from the substrate relative to the fixed layer; and

4 an underlayer adjacent to the first ferromagnetic film on the side of the substrate
5 comprises a stack of NiFeCr, NiFe, PtMn and Ru, or a stack of NiFeCr, NiFe, PtMn and Cu, in
6 order from the side of the substrate.

1 21. A magnetoresistive head according to claim 6, wherein:
2 the fixed layer is on the side of a substrate and the free layer is on a side remote
3 from the substrate relative to the fixed layer; and
4 an underlayer adjacent to the first ferromagnetic film on the side of the substrate
5 comprises a stack of NiFeCr, NiFe, PtMn and Ru, or a stack of NiFeCr, NiFe, PtMn and Cu, in
6 order from the side of the substrate.

1 22. A magnetoresistive head comprising:
2 a first pinned layer;
3 a second pinned layer;
4 a free layer;
5 a non-magnetic spacer film formed between the first pinned layer and the free
6 layer; and
7 another non-magnetic spacer film formed between the second pinned layer and
8 the free layer;
9 wherein each of the first and the second pinned layer has a first ferromagnetic
10 film and a second ferromagnetic film anti-ferromagnetically coupled with each other by way of
11 an anti-ferromagnetic coupling film; and
12 a coercivity of the first ferromagnetic film is 200 Oe or more and a coercivity of
13 the second magnetic layer is 20 Oe or less.

1 23. A magnetoresistive head comprising:
2 a first pinned layer;
3 a second pinned layer;
4 a free layer;
5 a non-magnetic spacer film formed between the first pinned layer and the free
6 layer; and

7 another non-magnetic spacer film formed between the second pinned layer and
8 the free layer;

9 wherein each of the first and the second pinned layer has a first ferromagnetic
10 film and a second ferromagnetic film anti-ferromagnetically coupled with each other by way of
11 an anti-ferromagnetic coupling film; and

12 wherein a composition of each of the first ferromagnetic films disposed in each of
13 the first pinned layer and the second pinned layer is within a range of: $\text{Co}_{100-x}\text{Fe}_x$ (at%) $40 \leq X$
14 ≤ 80 , and

15 a composition of the second ferromagnetic film is within a range of: $\text{Co}_{100-y}\text{Fe}_y$
16 (at%) $0 \leq Y \leq 20$.

1 24. A magnetoresistive head according to claim 22 or 23, wherein each of the
2 anti-ferromagnetic coupling films of the first pinned layer and the second pinned layer is made of
3 Ru and has a thickness within a range from 3.0 to 4.0 Å.

1 25. A magnetoresistive head according to claim 22 or 23, wherein a relation
2 between the imaginal thickness DA0 of the first ferromagnetic film that has a magnetic moment
3 equal to the magnetic moment of the second ferromagnetic film and a thickness DA of the first
4 ferromagnetic film satisfies:

5 $0.0227 \leq (DA - DA0)/DA0 \leq 0.136$.

1 26. A magnetoresistive head according to claim 25, wherein the magnetic
2 moment of the first ferromagnetic film is larger than that of the second ferromagnetic film.

1 27. A method of manufacturing a magnetoresistive head comprising a pinned
2 layer having a first ferromagnetic film and a second ferromagnetic film anti-ferromagnetically
3 coupled with each other by way of an anti-ferromagnetic coupling film, a free layer and a
4 permanent magnet film disposed at an end of the free layer, said method comprising:

5 a first magnetic field application step of applying a magnetic field in a desired
6 direction different from a direction of a magnetic moment magnetized to the pinned layer; and

7 a second magnetic field application step of applying a magnetic field in a
8 direction different from the direction of the magnetic field application in the first magnetic field
9 application step.

1 28. A method of manufacturing a magnetoresistive head according to claim 27,
2 wherein the following relation is satisfied:

3 $H_1 \geq 0.4 H_s$

4 $H_c \leq H_2 \leq 0.35 H_s$,

5 where

6 H_s is a saturation magnetic field that brings respective magnetic moments of the first
7 ferromagnetic film and the second ferromagnetic film antiparallel to each other into a parallel
8 state,

9 H_c is the coercivity of the permanent magnetic layer,

10 H_1 is a magnitude of an application magnetic field in the first magnetic field application
11 step, and

12 H_2 is a magnitude of an application magnetic field in the step of applying the second
13 magnetic field.